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Potential Effects of pipeline Rights-of-Way on the Densities and Movement of Boreal Mammals

by

Michael Patrick Marklevitz

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the

requirements for the degree of *Master of Science*

in

Conservation Biology

Department of *Renewable resources*

Edmonton, Alberta

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Faculty of Graduate Studies and Research

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Date: Sept. 30, 2003

Abstract

Linear disturbance resulting from increasing petroleum development is widespread in the mixedwood boreal forest of Canada. Despite the prevalence of pipelines on the landscape, their effects on the mammalian fauna are largely unknown. I examined the effects of buried pipeline rights-of-way (ROWs) on three species in Alberta: the northern flying squirrel (Glaucomys sabrinus), the red squirrel (Tamiasciurus hudsonicus), and the American marten (Martes americana). Using mark-recapture, I looked at three width classes of ROW and compared associated effects on population densities in forest adjacent to ROWs, capture success near ROW edges, and movement across ROWs. Only red squirrels had density responses and flying squirrels and marten had higher numbers near edges. Only one red squirrel and three marten were detected crossing ROWs and no individuals crossed the widest ROWs. This study suggest that pipeline ROWs may have long-term negative effects on movement of flying squirrels and possibly marten.

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Chapter 1. Potential Effects of Pipeline Rights-of-Way on the Densities and Movement of Boreal Mammals

1.1 Introduction

The boreal zone is the largest, forested ecosystem on the planet and the largest biome in North America. It stretches across North America from Alaska and the Yukon in the west, to Labrador and Newfoundland in the east, and in its entirety, comprises 28% of the total land area of Canada and the U.S. The boreal forest has evolved in response to the regular occurrence of natural fires that influence stand age, size, and composition (Eberhart and Woodard 1987, Cumming 1997, Johnson et al. 1998). The result is a complex mosaic of flora in various stages of succession. The continuity of this forest matrix has allowed forest-adapted mammals relatively unrestricted movement while seeking out specific niches and habitats.

Currently, the boreal forest of Canada, particularly in Alberta, is facing increasing demands and alterations from widespread industrial utilization of various natural resources (Schneider 2002). Virtually the entire extent of northern Alberta has been allocated to at least one and often several overlapping forms of resource extraction. Northward agricultural expansion, large-scale logging of both coniferous and deciduous forests, oil and gas exploration, and associated habitat alterations have presented new challenges to natural resource management. Related management decisions must be informed by relevant scientific research to be effective in achieving government-mandated goals of maintaining biological diversity (AEP 2000).

In the past, human-induced change in the western boreal was primarily limited to local scales. However, recent and widespread intensification of human activities is forcing fauna to cope with change over much larger spatial extents (AEP 1998, AEUB 1999). Over the past few decades, clearcuts, well sites, and linear disturbances (e.g. roads, seismic lines, and pipeline rights-of-way) have resulted in habitat modification and fragmentation. The long-term cumulative effects of these alterations are only now beginning to be addressed through comprehensive research. Previous and ongoing research in Alberta has dealt with biotic response to various aspects of development, much of it centered on high profile species, such as fragmentation effects on disturbance of grizzly bears (Gibeau and Herrero 1998), changes in wolf-caribou dynamics, and caribou avoidance of linear corridors (Dyer 1999a, James and Stuart-Smith 2000). In addition, research on songbird response to fragmentation has been conducted (e.g., Schmiegelow et al. 1997, Fleming 2001, and see review in Schmiegelow and Monkkonen 2002), and projects such as EMEND (Spence et al. 1999) are examining harvesting effects on a broader suite of species. Despite these initiatives, parameters of acceptable disturbance levels relative to the adaptive capabilities of boreal species have not been identified.

Here, I focus on disturbances related to the rights-of-way associated with buried pipelines. Petroleum product pipelines are ubiquitous throughout Alberta, as evidenced by statistics showing that in the year 2000, oil and gas pipelines in Alberta totaled 293,799 km, exclusive of inter-provincial pipelines (ARD 2001). Despite their proliferation across the landscape, studies examining the influence of pipeline rights-of-way on mammals in Alberta are virtually non-existent.

The original intent of my study was an examination of the effects of pipeline rights-of-way on northern flying squirrels (*Glaucomys sabrinus*). However, trapping results in the first year allowed for the inclusion of data on American red squirrels (*Tamiasciurus hudsonicus*) and American marten (*Martes americana*). All three species are widespread and active year round in the boreal zone of Alberta, and none are currently regarded as threatened in Alberta (AEP 2000). Relative mobility between the 3 species varies: the flying squirrel is primarily an arboreal volant species with limited terrestrial mobility, the red squirrel is both arboreal and terrestrial, and the marten is mainly terrestrial but with some ability to move through trees. Both northern flying squirrels and American marten have exhibited adverse reactions to habitat alteration or associated fragmentation in other jurisdictions. As a result, these species have been proposed as possible indicator species for the health of forests (Maser and Mazer 1988, Hall 1991, Thompson 1991).

1.2 General Biology

1.2.1 Northern Flying Squirrel

Northern flying squirrels inhabit coniferous, mixedwood, and deciduous forests in a range that extends from Alaska down to Utah in the west, and across the boreal zone and down along the mountains to the Carolinas in the east (Banfield 1974, Woods 1980, Novak 1999). Populations at the extremes of the southern range in the east are listed as threatened because of habitat loss attributed to urbanization and agriculture (Weigl 1977, Odum et al. 2001). In Alberta, they are present throughout the boreal, montane, and parkland vegetation zones (Soper 1964, Pattie

and Fisher 1999). Older forest age classes are preferred due to dependence on snags and natural cavities for den and rearing sites (Weigl and Osgood 1974, McDonald 1996).

Northern flying squirrels measure 25-37 cm in length, including a tail of 11-18 cm, and weigh 75-185 g. The patagium, a gliding membrane, extends from wrist to ankle, making this the sole western Canadian mammal adapted for gliding as a primary source of locomotion. *Glaucomys* glides well at a steep angle, with record distances of 100 m, presumably on sloping ground (Klugh 1924, Novak 1999, Wilson and Ruff 1999). However, individuals on level terrain lose height rapidly, at an angle of approximately 40% and have limited maneuverability in flight (Wells-Gosling 1985, Rezendes 1992). Adaptations for gliding while conferring advantages arboreally, impede the terrestrial mobility of this species, rendering it slower and less agile than red squirrels (personal observation).

Northern flying squirrels are increasingly viewed as important components of the forests they inhabit. Their diet consists of buds, berries, the seeds of conifer cones, arthropods, eggs, and nestlings, with a heavy reliance on lichens and fungi (Maser et al. 1978, Wells-Gosling 1985, Hall 1991). Research indicates that they play an important role in forest ecology, both as consumers and distributors of hypogeal fungal spores (Trappe and Maser 1976, Fogel and Trappe 1978, Maser et al. 1985, Carey et al. 1999). These fungi act as obligatory ectomycorrhizal symbionts with many tree species. Thus, flying squirrels play a fundamental role in forest ecosystem health (McKeever 1960, Maser et al. 1985, Hall 1991), and may be considered a "keystone species".

A paucity of records, due to a strictly nocturnal lifestyle, has led to the underestimation of historical densities of flying squirrels. Incidental catch by fur trappers was often the only indication of this species presence, but current research has revealed them to be sufficiently abundant in some habitats to serve as an important prey item for various species, notably owls (Teeple 1983, Carey 1993, Rosenberg et al. 1994).

The sole additional member of this genus, the southern flying squirrel (*Glaucomys volans*), is a common native of Carolinian forest in the United States, reaching the northernmost limits of its range in southern Ontario and Quebec. It is considered under threat in Canada due to fragmentation and modification of habitat (Stabb and Aird 1990, OMNR 2002). The Eurasian boreal forest is inhabited by a sympatric species, the European flying squirrel (*Pteromys volans*). Volant adaptation in this species is not as fully developed as in *Glaucomys* (Novak 1999). *Pteromys* is currently the object of concern in the Fenno-Scandian nations as a result of large-scale land conversion and forestry practices, with resultant fragmentation and habitat alteration (Monkkonen et al. 1997, Reunanen et al. 2001).

1.2.2 American Red Squirrel

The red squirrel is the familiar diurnal squirrel of the forested regions of Canada. This species ranges across Canada and Alaska extending down the mountains of New Mexico in the west and Virginia in the east (Banfield 1974, Burt and Grossenheider 1976). In Alberta, red squirrels are found in boreal, montane, and parkland regions and prefer woodland containing some coniferous component (Soper 1964, Pattie and Fisher 1999). Red squirrels are both terrestrial and arboreal, and den in snags, tree holes, and self-made dreys in trees in the warmer months, and excavate holes in the ground and under the snow in the winter (Soper 1964, Banfield 1974, Woods 1980).

Red squirrels are slightly larger than flying squirrels, attaining a length of 28-35 cm, including a tail of 11-15 cm, and a weight of 170-310 g. Conifer seeds constitute a predominate food resource, but the varied diet also includes bark and cambium, flowers, birds, berries, fungi, eggs, nestlings, small mammals, and arthropods (Woods 1980, Novak 1999). Conifer seeds are cached in middens that may reach several bushels in size and may constitute an important food and shelter resource for other species such as marten and weasels (*Mustela* spp.) (Sherburne and Bissonette 1993, Lisgo 1999). They are an abundant and important prey species for owls, hawks, short-tailed weasels and marten, (Banfield 1974, Lisgo 1999) and are still subject to harvesting for fur.

1.2.3 American Marten

The range of the American marten stretches south from southern Alaska and the Yukon along the western mountain ranges to northern California in the west, and extends east across the north to Newfoundland and down into Maine (Banfield 1974, Novak 1999). Marten are found throughout the boreal and montane zones of Alberta (Pattie and Fisher 1999, AEP 2000). Formerly, the range included parts of the transition zone between boreal and parkland, but there has been a range contraction, possibly due to habitat loss and land-use alteration over the latter half of the last century (Soper 1964, Peterson 1966, Godin 1977).

All populations are currently classified as belonging to a single species although some research indicates that specimens inhabiting the west coast and southern Rockies may constitute a separate gene pool ("*Martes caurina*" subspecies group). The animals included in this study are representative of the eastern population ("*Martes americana*" subspecies group) (Clark et al. 1987). Marten at the extremes of their current range in California, the Queen Charlotte Islands, and Newfoundland are considered endangered, with the primary reason assumed to be habitat alteration caused by intensive forestry, sometimes in combination with trapping pressure (Thompson 1991). Conversely, in some previously harvested forests, populations appear to be reestablishing themselves as the forest ages (Mech and Rogers 1977, Litvaitis 1993). Other members of the genus *Martes* occur in northern Europe and Asia and *Martes melqampus*, *M. zibellina*, and *M. martes* are considered by some to form a super-species complex with American marten (Buskirk 1992). These taxa have also seen range contractions as habitat is anthropomorphically altered. This, in

combination with harvesting for fur, has led to the extinction of some local populations (Gibilisco 1994).

Marten are a medium-size mustelid with a length of 49-65 cm including a tail of 14-20 cm, and a weight of 0.6-1.3 kg. Pelage ranges from golden or reddish-brown through almost black with a throat patch of white to yellow to rich orange that differs enough to allow individual identification.

Marten are both diurnal and nocturnal and primarily terrestrial, but good tree climbing ability allows them to utilize arboreal denning and resting sites (Grinnel et al. 1937, Wynn 1981), and anecdotal evidence attributes an ability to forage arboreally (Seton 1929). Studies have indicated a high dependence on voles as staple prey, but the complete diet is wide-ranging and includes squirrels, birds, eggs, berries, and snowshoe hares (Murie 1961, Buskirk 1983, Zielinski et al. 1983).

1.3 Objectives of My Study

The objectives of my study were to: 1) examine the effects of varying widths of pipeline rights-of-way on the densities of northern flying squirrels, American red squirrels, and American marten in older aspen-dominated, boreal mixedwood forests of northwestern Alberta; 2) explore whether pipeline ROWs constitute a barrier to movement for these three species and if so, whether there is a threshold width that impedes or curtails movement for any species; and 3) discuss the implications of my findings with respect to current industrial practices.

Chapter 2. The Influence of Rights-of-Way on the Densities of Squirrels and Marten

2.1 Introduction

Northern Alberta is predominantly covered in boreal mixed-wood forest, which is currently experiencing a high rate of exploitation by a variety of resource extraction industries. Thousands of kilometers of roads, seismic lines, transmission lines, and pipeline rights-of-way (ROWs) now crisscross the north, as a result of exploration and development for oil and gas (Pratt and Urquhart 1994, Schneider 2002). In 1998, there were 263 968 km of pipeline right-of-ways alone in Alberta (AEUB 1999). Despite their proliferation on the landscape, the effects of linear disturbances on wildlife have been little studied.

Some research suggests that linear disturbances can affect the distribution, movement, and population dynamics of some species (e.g., Peles et al. 1999). Research on ROWs has examined the effects of roads, ditches, transmission lines, and above-ground pipelines on wildlife taxa including birds (Anderson et al. 1977, Kroodsma 1982, Fleming 2001), small mammals (Diffendorfer et al. 1999), and ungulates (Morhardt et al. 1984, Dyer 1999b). However, there has been little research conducted on furbearers. In addition, virtually none of the research has addressed the effects of ROWs associated with below-ground pipelines.

Pipeline ROWs differ in several respects from many other linear disturbances. For example, pipeline rights-of-way lack infrastructure (e.g., relative to transmission lines), experience relatively little human traffic, and due to the recent sharing of

rights-of-way by multiple interests, result in gaps approaching one hundred meters. These differences may have significant implications for biotic response.

Densities of animals are often utilized as a comparative benchmark when assessing population response. For example, densities have been used to delineate optimal versus sub-optimal habitat: some vole and mouse species are restricted to what is deemed to be optimal habitats during periods of low population density, then increasingly invade suboptimal habitats as densities increase (Morris 1991, Ostfeld 1992). The density of a population can be affected by a variety of natural factors, such as disease, weather, habitat quality, and availability of resources (e.g., den sites, food resources, or habitat). In human-impacted systems, hunting, trapping, livestock diseases, resource extraction, and habitat alteration can also affect animal densities (Batzli et al. 1999, Lidecker and Peterson 1999).

Marten and squirrels are species whose home range size and population density allow for examination of faunal response to ROWs in boreal forests. A variety of factors associated with linear disturbances may affect the population densities of marten and squirrels. The most discernable factor is the loss of habitat, which could directly affect the availability of resources. The areas immediately adjacent to the ROWs may also be subject to edge effects. Edge effects such as changes in vegetation structure, microclimate, faunal community, and predator activity could alter population densities of sensitive species (Lidecker and Peterson 1999, Ostfeld et al. 1999). The ROWs may also facilitate the movement of diurnal raptors and owls (Voous 1988), and coyotes, all known predators of marten and squirrels . The

increased presence of predators may reduce the quality of habitat adjacent to the ROWs, and therefore, densities of marten and squirrels.

The impact of pipeline rights-of-way on squirrel and marten populations in Alberta is unknown. Elsewhere however, habitat loss, edge effects, and roads, have all been identified as factors contributing to declines in density (Soutiere 1979, Thompson and Harestad 1994, Monkonnen et al. 1997). Therefore, the presence of pipeline ROWs may similarly influence the local densities of marten and squirrels in Alberta forests.

In this Chapter, I ask two questions: 1) does the presence and width of pipeline ROWs through areas of older forest influence the densities of American marten, American red squirrel, and northern flying squirrel, and 2) are densities of these species influenced by distance from edge of the ROWs. I predict that densities of all three focal species will be adversely affected both through loss of habitat to the ROWs and as a result of proximity to the ROWs.

2.2 Methods

2.2.1 Study Area

The study was conducted 40-kilometers south of Grande Prairie, Alberta, within the boreal mixedwood forest at Townships 67 Range 3 to 5, and Townships 68 Range 4 to 6, west of the 6th meridian.

The dominant tree species in my study plots was trembling aspen (*Populus tremuloides*), with significant numbers of balsam poplar (*Populus balsamifera*), white spruce (*Picea glauca*), and black spruce (*Picea marianna*). Topography is varied,

with a major river, the Smoky, bisecting the area, and several small creeks running adjacent to study plots. Industrial activity in the area is high and continued to increase during this study. Timber extraction in the form of small clearcuts was ongoing, two gas plants are located within the area, and numerous well sites, both old and newly drilled, exist. Small pipeline rights-of-way connect wells to the main lines, and a major pipeline transects the area. Road building is extensive and ongoing and the forest is interspersed with cutlines, both recent and in varying stages of regrowth. Two cattle grazing leases exist in the area.

2.2.2 Site Selection

Study sites, consisting of a sampling grid located at and away from pipeline ROWs of varying width, were initially located using Alberta Phase 3 Vegetation Inventory maps, then ground-truthed to verify that forest stand types matched the treatment/control pairings. Stands selected were greater than 70-80 years in age, 25 m in height, and deciduous dominated (see Table 2.1 for general site description). Two sites (5 and 6) were located on the Campbell Creek Grazing Reserve and subject to varying degrees of cattle grazing. Sites overlaid, where possible, previously sampled bird-sampling grids established by Warren Fleming in 1998-99 (Fleming 2001).

In the 2000 field season, 6 sites were established within 2 width classes of rights-of-way: medium (32-42 m) and large (72-92 m). Each width class was replicated 3 times. In 2001, 3 sites of a small-width class (15-27 m) were added.

Table 2.1: A general description of sites sampled comparing relative content of deciduous and coniferous trees in the forest canopy and relative density of the shrub layer.

		Treatment			Control		
Site	ROW Width	[1]Deciduous	[1]Conifer	[2]Shrub Layer	[1]Deciduous	[1]Conifer	[2]Shrub Layer
1	41.5 m	H	T	H	H	N	M
3	32 m	H	T-M	M	H	M	H
4	34 m	H	M	H	H	T	H
5	91.5 m	H	T	L	H	T	L
6	72 m	H	M	L	H	H	L
9	78 m	H	T	M	H	M	M
10	27 m	H	L	M	H	L	L
11	15 m	H	M	L	H	M	L
12	24 m	H	L	H	H	L	H

[1] Codes refer to the relative content of deciduous trees(trembling aspen, balsalm poplar, and/or birch) and coniferous trees (white spruce) between grids N=none, T=trace, M=moderate, H=high

[2] Codes refer to the relative density of the shrubby layer between grids: L=low density, M=moderate density, H=high density

Each site consisted of a treatment and control grid. The treatment grids were centered over the pipeline rights-of-way. Four of the sites were widened in the winter previous to sampling. The rights-of-way of the large-width class (sites 5, 6, and 9) were widened approximately 30 m with timber cleared in the winter of 1998-99 and the pipe layed in winter 1999-2000. Site 10 of the small-width class was widened in the winter of 2001 by 9 m. One large-treatment grid (site 9) was lost to logging in the winter (2000-2001), between field seasons. It was re-established immediately adjacent to the original site, with a 100-m overlap. At each site, the control grid was located a minimum of 200 m from the treatment grid. When possible, the control grid was oriented in the same direction as the treatment, parallel to the right-of way, as was the case for sites 2-9. At site 1, the control grid was oriented parallel to an

adjacent pipeline. Extensive and ongoing industrial modification of forest patches severely limited the choice and this resulted in 2 sites (1 medium, 1 small) being located in close proximity (< 1 km) to a sour gas pumping station.

2.2.3 Sampling Grids and Trap Setup

Each 300-m by 500-m trapping grid consisted of 24 traps, spaced at 100-m intervals, encompassing an area of 15 ha (See Figure 2.1). Tomahawk single entry, live-capture traps were used. Traps were mounted with nails and wire on the largest tree within 5 meters of the intersection of grid lines, excepting 11 cases where lack of suitable trees necessitated utilizing the largest tree within 10 meters. Traps were attached 1.5-2 m above ground, oriented horizontally on the tree trunk. Bedding consisting of raw cotton was placed in the back of the trap to guard against hypothermia in the captured animals. Two pieces of plywood measuring 15x30 cm were attached with elastic bands to the top and bottom of the trap to provide a measure of security against predation and to give better footing. A plastic freezer bag was then placed around the back 2/3 of the trap to protect captured animals against inclement weather and to keep the bedding dry. Bags were often torn by trapped animals and were regularly replaced.

2.3.4 Bait

Traps were baited with water-soaked black oil sunflower seed and peanut butter (5-7 tablespoons). Slices of apple were added nightly to provide a moisture source. Pre-baiting a week in advance of trapping was conducted in 2000. This

consisted of smearing the tree at trap height with peanut butter and sunflower seed and placing additional sunflower seed on the ground at the tree base. A combination of heavy rains, and removal of the pre-bait by bears rendered this inefficient, and it was discontinued in 2001.

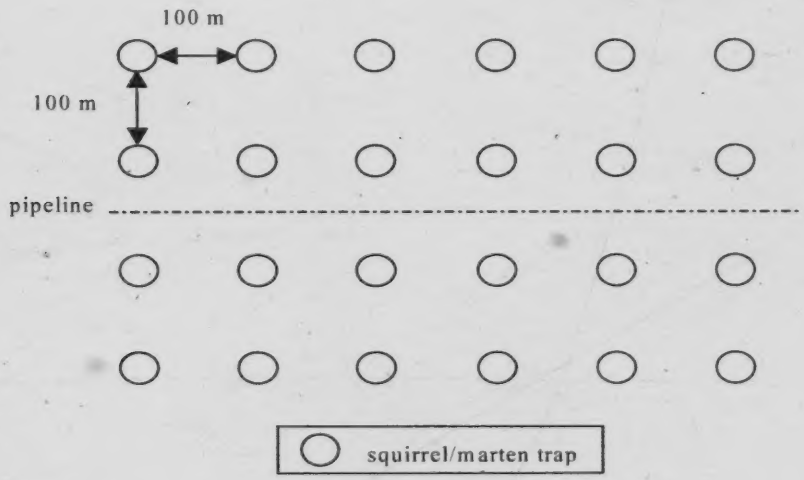

Figure 2.1: Grid overlay of pipeline right-of–way showing distribution of traps.

2.3.5 Trapping Season, Duration and Daily Schedule

In both 2000 and 2001, 2 rounds of trapping were conducted. In 2000, trapping began June 7 and ended July 30. In 2001, trapping began on July 2, and the 2 rounds were completed on October 9. The 2001 trapping season began in July, rather than in June, because capture success in June 2000 was very poor, and was extended into October in an attempt to capture dispersing juveniles. During Round 1 of the 2000 field season, sites were trapped for 3 consecutive nights. This was extended to 5 consecutive nights in Round 2 in an attempt to increase the number of captures, as

well as to increase the efficiency of field logistics. Both sampling rounds of the 2001 field season consisted of 5 consecutive nights of trapping. Each sampling round consisted of the simultaneous trapping of the treatments and controls in 2 sites, for a total of 96 traps set during a single night. Traps were set each evening between 1730hrs and 1830hrs and checked the following morning between 0600hrs and 1030hrs. Traps were closed during the day. Traps were not set on nights of heavy rain or wind because of low squirrel activity and safety concerns.

2.3.6 Animal Handling

Trapped squirrels were transferred to a "sock" made of soft canvas and mesh. Animals were then weighed using a hand-held Pesola scale, and examined to determine age (adult or juvenile), sex and general physical condition. Prior to release each animal was marked with a numbered aluminum ear tag, and released at point of capture. It was necessary to restrain some flying squirrels with a gloved hand to ascertain sex.

American marten had not initially been targeted as a study species but were included due to high trapping success in 2000. In the initial field season marten were not handled, as our handling socks would not hold them. Notation of highly individual pelage color, bib shape and color and ear notches allowed for identification of re-trapped individuals. A larger version of the squirrel holding sock was obtained for the 2001 field season and marten were then handled and tagged using the same method utilized for squirrels.

2.3.7 Data Analysis

To address the first question, does the presence and width of pipeline ROWs through areas of older forest influence the densities of American marten, American red squirrel, and northern flying squirrel, I compared the differences in capture rates of each species, and for all species combined, between treatment and control sampling grids. To address the second question (edge effects), are densities of these species influenced by distance from edge of the ROWs, I compared the capture rates of trap lines positioned adjacent to the ROW (inner lines) to the capture rates of trap lines positioned away from the ROW (outer lines), in the treatment and control grids, for each species and for all species combined. I define capture rate as the number of captures per trap night, for each grid in each year.

I examined both questions using generalized linear models (GLM), in particular, employing analysis of variance for one dependent variable by one or more factors and/or variables (Dyer 1999a). This procedure allows investigation of the effects of individual factors and interactions between factors. In analyses for both questions, my dependent variable was capture rate, per grid, in each year, for each species. The factors used in evaluating overall density were year, treatment, and width, based on treatment-control comparisons. The factors used in evaluating potential edge effects were year, position, width, and I compared inner grid line capture rates (lines positioned closest to the ROW edge) with outer line capture rates (lines positioned at the outer edges of the grid).

Prior to conducting analyses, I tested my capture rate data for violation of the assumption of normality using the Kolmogorov-Smirnov test (Zar 1974), and for

homogeneity of variance using the Levene test (Dyer 1999a). Because the data violated these assumptions, I log-transformed capture rates, which resulted in normal distributions and eliminated heteroscedasticity.

The p-value for all tests was set at 0.10 to lessen the possibility of a Type 2 error, and I used a Bonferroni correction to adjust for multiple comparisons when conducting post-hoc pair-wise tests for significance. I also calculated the effect size and power of each factor in order to evaluate potential biological significance. SPSS Version 11.5 statistical software (Norusis) was used for all analyses.

2.4 Results

In 2000 and 2001, 183 and 156 individuals resulted in the identification of a total of 322 and 265 captures, respectively (Table 2.2). Total for both marten and red squirrels declined substantially in 2001 despite 2016 additional trap nights (2 additional days of trapping on medium and large ROWS, and 3 new sites on small ROWs. In contrast, flying squirrel numbers in the second year were double the number trapped in the first year. Trapping results across differing width classes are illustrated in Table 2.3.

Density Effects

I tested for overall density effects on trapping grids on and away from ROWs by comparing capture rates between treatment-control pairings. Treatment effects were not significant for any of the species evaluated (Table 2.4; p=0..84-0.90). While the power of these tests was low, effect sizes were also very small (Table 2.4), suggesting that differences were neither statistically nor bilologically significant.

Width effects were significant for flying squirrels (p-0.091) and red squirrels (p=0.007); a treatment* width interaction was also significant for red squirrels (p=0.071; Table 2.4). Capture rates for flying squirrels were higher on the grids established at and away from large ROWs, when compared to either medium or small ROW sites, although post-hoc pairwise comparisons were not significant (p=0.17 and 0.24, respectively). Capture rates for red squirrels were significantly higher at large ROW sites than either medium or small ROW sites (p=0.032 and 0.018, respectively), and treatment*width interactions suggested that differences for control grids were more pronounced than those for treatment grids (comparison of 90% confidence intervals). Year effects were strong and significant for both red squirrels and marten (Table 2.4); capture rates for both species were lower in 2000 than in 2001.

Edge Effects

I tested for potential edge effects by comparing capture rates on inner and outer pairs of lines in trapping grids that encompassed pipeline ROWs. Line position was significant for flying squirrels only (p=0.018; Table 2.5), however contrary to my prediction, capture rates were higher on lines adjacent to pipeline ROWS, for all widths. The power of the tests for red squirrels and marten was low, but the effect sizes were also very small (Table 2.5). A significant year effect was apparent for both red squirrels (p=0.01) and marten (p=0.001), as per the previous analyses.

Table 2.2: Total number of individuals captured, by species, in trapping efforts at and away from pipeline ROWs, near Grande Prairie, Alberta, in summer 2000 and 2001.

Year	Species	Number of Individuals	Number of Captures
2000	Flying Squirrel	25	34
2000	Red squirrel	115	218
2000	American Marten	43	70
2001	Flying Squirrel	50	85
2001	Red Squirrel	79	131
2001	American Marten	27	49

Table 2.3: Total numbers of individuals captured in control and treatment grids for small-, medium-, and large-width pipeline ROWs. The value in parenthesis is the total number of captures. total number of captures. The number suffixed by a y is the number of individuals trapped in 2000 and recaptured in 2001.

Year	Species	Small Width		Medium Width		Large Width		All Widths Combined	
		Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
2000	Flying Squirrel	n.a.	n.a.	7(8)	6(9)	7(10)	5(7)	14(18)	11(16)
2000	Red Squirrel	n.a.	n.a.	10(18)	32(56)	47(98)	26(46)	57(116)	58(112)
2000	Marten	n.a.	n.a.	9(21)	12(16)	10(15)	12(18)	19(36)	24(34)
2001	Flying Squirrel	5(9)	6(8)	4(15)1y	3(4)	13(29)3y	19(31)5y	22(43)4y	28(43)5y
2001	Red Squirrel	2(5)	2(4)	5(5)3y	15(20)6y	38(70)21Y	18(27)4y	45(80)24y	35(51)10y
2001	Marten	8(12)	6(8)[a]	4(4)	3(4)	4(14)	4(7)	16(30)	13(19)[a]

[a] 2 individuals also recorded in an adjoining control plot

Table 2.4 Results for analysis of capture rates of northern flying squirrels, red squirrels, and marten for differing width classes of pipeline rights-of-way and control pairings, near Grande Prairie, Alberta, in summer 2000 and 2001.

Species	F	Sig.	Effect Size	Observed Power
Northern Flying Squirrel				
Year	0.148	0.704	0.006	0.124
Treatment	0.019	0.892	0.001	0.103
Width	2.671	**0.091**	0.188	0.615
Treatment/Width	0.099	0.906	0.009	0.121
Red Squirrel				
Year	7.165	**0.013**	0.238	0.829
Treatment	0.016	0.899	0.001	0.103
Width	6.142	**0.007**	0.348	0.915
Treatment/Width	2.981	**0.071**	0.206	0.658
Marten				
Year	8.692	**0.007**	0.274	0.888
Treatment	0.041	0.842	0.002	0.106
Width	1.071	0.359	0.085	0.327
Treatment/Width	0.073	0.930	0.006	0.115

Table 2.5 Test statistics for comparisons of individuals captured at inner and outer lines of treatment grids, for all species, all width classes, and both years.

Species	F	Sig (P-Value)	Effect Size	Observed Power
Northern Flying Squirrel				
Year	0.427	0.520	0.018	0.168
Position	6.454	**0.018**	0.219	0.794
Width	1.553	0.233	0.119	0.424
Position/Width	0.892	0.424	0.072	0.290
Red Squirrel				
Year	7.837	**0.010**	0.254	0.858
Position	0.023	0.882	0.001	0.104
Width	1.291	0.294	0.101	0.372
Position/Width	0.441	0.649	0.037	0.194
American Marten				
Year	13.672	**0.001**	0.373	0.974
Position	1.621	0.216	0.066	0.343
Width	1.153	0.333	0.091	0.344
Position/Width	1.180	0.325	0.093	0.350

2.5 Discussion

My primary objective was to examine the effects of varying widths of ROWs on the densities of three focal species (American marten, American red squirrel, and northern flying squirrel) in adjacent habitats. I also examined whether edge avoidance occurred in response to the ROWs. I predicted that the densities of all three species would be adversely affected by the presence of the ROWs. I also predicted that edge effects would be a factor that resulted in lower numbers of all three species in the lines nearest the ROWs with effects increasing with corresponding increases in ROW width.

My predictions regarding density were not supported. None of the species examined showed any significant differences in capture rates (used as a proxy for density) on grids positioned on and away from ROWs of varying width, during the 2 years of this study. While sample sizes were relatively small, and resultant power of the tests low, the effect sizes were also very small (<5%), implying that the comparisons also lacked biological significance, and the abscence of differences given the sampling regime were real. While some effects of ROW width were apparent for both flying squirrels and red squirrels, there was no treatment by width interaction for flying squirrels, and the treatment by width interaction for red squirrels was not strong, suggeating thast this result was due more to overall site-level differences in habitat quality, rather than the effects of the ROWs per se.

Similarly, my predictions regarding edge effects were also not supported. In fact, the result for flying squirrels was counter to what I had suspected, with higher capture rates recorded on on trap lines adjacent to ROWs, than those farther away,

within the treatment grids. As overall densities did not differ between treatment and control grids, this suggests that captures in treatment grids are concentrated along the ROW edges.

I explore several explanations for my results, including the following: 1) the three species studied are able to compensate for direct habitat loss, 2) the sampling grids used in this study were small relative to the home range of these species, and thus effects were diluted, 3) the areas adjacent to the ROWs have enhanced habitat valu, and 4) the ROW edges act as territory delineators.

I found no evidence that direct loss of habitat to the ROWs influenced numbers of my focal species, which is surprising, given that the largest ROWs accounted for almost 30% of the sampling grid in these sites. Red squirrels are the focal species most strongly associated with success in fragmented forest areas, reaching some of their highest densities there, and may not exhibit a strong evidence of avoidance of these openings (Swihart and Nupp 1998). They were also the species which was most strongly represented in the total captures accounting for over half of all capture and a high number of recaptures. Marten are known to be adversely affected by forest loss (Soutiere 1979, Gibilisco 1994), and to avoid areas without overhead cover (Soutiere 1979, Spencer et al. 1983, Hargis and McCullough 1984), but that was not reflected in this study. Some evidence indicates marten are more likely to avoid areas devoid of substantial cover in the northern extremes of their range (Buskirk 1983). Marten also have the largest home range and the greatest mobility of the three species studied, and my sample units may have been small relative to the regular movement patterns of marten in the area. My results are

somewhat puzzling for flying squirrels. As the least terrestrially adapted of he three species in my study, I assumed it would be the most dependent on contiguous forested habitat. The lack of significant capture rates associated with even the largest ROW grids, relative to the control grids, indicates that amount of habitat is not the only consideration important for interpreting flying squirrel density in the grids in my study. In particular, the role of potential edge effects must be evaluated.

Attraction to edge of adjacent open areas may occur for a number of reasons. A wider opening adjacent to intact forest might result in alterations of habitat through effects such as increased windfall and subsequent changes to forest structure such as greaer surface litter. Vegetative changes associated with greater light levels or invasion by plant species not associated with forest interior could alter food resources. Studies have demonstrated that marten hunt along forest edges to take advantage of higher prêt numbers (especially *Microtus* sp.) in these habitats (Simon 1980, Buskirk and Powell 1994, Martin 1994). Thus limited habitat loss or alteration might not result in adverse effects on the overallprey base and perhaps in specific instances serves to foster conditions enhancing availability of mocrotine or other prey. Such habitat compensation might also occur for otherspecies included in this study (red and flying squirrels). Conversely, ROW edges may form whole or partial barriers, and as a result, channel movements parallel to the ROW thus increasing the odds that another trap along the line will be encountered. ROW edges could also correspond to, or even define, home range borders and movement along such perimeters could similarly increase the likelihood of capture relative to areas within the interior of the home range. Unfortunately, the identification of causal factors is

beyond the scope of my study, but the particularly interesting pattern of increased capture rates of flying squirrels adjacent to the pipeline ROWs warrants further investigation.

Limitations of this study

Capture rates for all three target species, and more importantly, recapture rates, were not high enough to estimate actual densities for the sampling grids I used. A study design incorporating more intensive trapping, and across different times of the year, and using larger sampling grids, might have obtained more representative numbers. However, no established standards exist for populations of these species in the habitat and range sampled, making it difficult to judge typical populations in older aspen-dominated mixed wood.

Trapping was initiated in early summer, while young were still dependent and movement and subsequently capture rates may have been limited at this time. The greater number of flying squirrels captured in 2001 may have resulted from this change in sampling. The initial trapping round in 2000 resulted in the lowest ratio of capture per trap nights during the project. Trapping was initiated later in the season in the second year of sampling in an attempt to increase trapping success.

The presence of relatively high numbers of marten, a known squirrel predator could have had an influence on overall population numbers of both species of squirrels. Bias may also have resulted from the overall anthropogenic impact in the area. Current populations may not be representative of pre-disturbance numbers. Marten populations have been shown to drop sharply when available habitat drops below specific levels (Soutiere 1979, Thompson and Harestead 1994) and given their

larger territorial needs they may be the most sensitive of my focal species to overall habitat losses at broader spatial scales.

There was a drop in captures of both red squirrels and marten between the first and second years while flying squirrels captures doubled. This apparent population reduction was also noted by researchers at a nearby study site (Samantha Song, personal communication). Red squirrel populations are known to cycle in population in response to cone crops and marten populations respond quickly to prey availability (Thompson and Colgan 1987, Martin 1994). No sampling was conducted to evaluate possible causes for these population changes. Commercial trapping for fur prior to the initial field season had been relatively high but marten and red squirrels were both numerous during 2000 (Ed Lightfoot 2001, personal communication, Campbell Creek Grazing Reserve, Grande Prairie, AB). Commercial trapping pressure was low during the winter between 2000 and 2001 due to inadequate snow cover and thus was unlikely to have caused the decline in populations.

My study design, in which grid lines were not at a constant distance from the edge of the ROW, may have hampered my ability to detect edge effects. This design was utilized in order to maintain standard grid sizes over all three ROW sizes and to keep inter-trap spacing constant. The resultant variability may have rendered a measure of response to edge problematic. A study design focusing on edge effects and standardizing grid distances from ROW edge might better answer this question. Capture rates were notably different between grids. Although care was taken to select similar forest the inherent variability in the plots selected could have been reflected in the widely varying capture rates between grids.

2.6 Conclusions

I found no evidence that ROWs were adversely affecting populations of flying squirrels and marten in my study area. However, the actual physical footprint of industrial activity is sometimes far exceeded by associated functional habitat loss. These effects are often not readily apparent but may result in indirect habitat losses through avoidance, stresses associated with extra movement, and overall population effects through alteration of social spacing of individuals and reduced reproductive success, that are important at a landscape scale. In Alberta, taxa as diverse as caribou (Dyer 1999b), songbirds (Desrocher and Hannon 1997, Fleming 2001, Schmiegelow and Monkkonen 2002), and grizzly bears (Gibeau and Herrero 1998) have exhibited varying degrees of adverse reaction to industrial development. The current rate of industrial activity in northern Alberta has resulted in very few areas that are free of human impacts. Meaningful long-range planning that attempts to reconcile industrial development with attempts to maintain biodiversity will have to include some determination of the overall functional habitat requirments of a host of boreal species.

Chapter 3. Crossing of Pipeline Rights-of-Way by Squirrels and Marten

3.1 Introduction

The movement of individual animals and connectivity of populations across the range of a species is important biologically, and increasing concerns are being expressed by scientists over widespread habitat alterations and the resultant impacts on fauna. Substantial, broad-scale changes to landscapes are proceeding rapidly in Alberta and other jurisdictions in northern and western Canada. One of the most widespread anthropomorphic footprints on Alberta's boreal mixedwood forest is the proliferation of linear disturbances (e.g. roads, seismic lines and pipelines). While these have been present in northern landscapes for several decades, their extent and density is increasing throughout northern Alberta. In addition, the width of individual disturbances is, in some cases, increasing, as multiple lines or line types are added to shared corridors. Linear disturbances associated with roads, transmission lines, and pipeline rights-of-way (ROWs) represent long-term habitat alterations, as these features are maintained free of most shrubby and woody vegetation.

One of the potential impacts of linear disturbances on wildlife is the impediment to movement of animals across the landscape. However, the degree to which pipeline rights-of-way function as barriers to movement is largely unknown. Most research has examined roads (Reed et al. 1996, Forman and Alexander 1998) and transmission lines, and in the arctic, aboveground pipelines (Cameron et al. 1979, Curatolo and Murphy 1986). Little overall research has been directed towards pipeline ROWs, and virtually none in the mixedwood boreal. The few studies of pipeline ROWs in Alberta have concentrated on caribou, large predators, and other

ungulate species. These studies, consistent with research in other jurisdictions, have found linear disturbances to negatively affect animal populations in various ways (Dominske 1997, Gibeau and Herrero 1998, Dyer 1999b, James and Stuart-Smith 2000).

Many studies of movement in small mammals have focused on individuals, populations, and communities at the patch scale (e.g., Peles and Barrett 1999). More recently, studies have sought to define the influences of structure at the landscape scale on populations of small mammals heretofore viewed mainly as subject only to small-scale pressures (Peles et al. 1999). They have also begun to take into account the movement probabilities and possibilities of individuals (Diffendorfer et al. 1999).

Movement in small mammal populations can be broken down into three categories (Peles and Barrett 1999). The first is exploratory or pre-dispersal movement, defined as movements undertaken beyond the usual range but with return to the home range after a relatively short period. The second, dispersal, entails an individual leaving its natal home to locate and establish itself in another home range. The last is comprised of movements within the home range itself, generally defined as the area in which an individual regularly resides. These types of movements serve varying purposes, including seeking food or den sites, mating opportunities, or possibly social contact with conspecifics. Movements may be age or sex specific or may reflect density pressures (Nichols and Coffman 1999).

Dispersal capabilities by individual species are often the result of evolutionary history. Species with histories in patchy habitats or ones in which resources are widely spaced or seasonal in nature, are generally assumed to have greater adaptive

characteristics and movement capabilities, while species whose origins are based in a stable, homogenous habitat are viewed as being less adaptive to change (Wolff 1999). Species whose biology incorporates specialized factors such as being fossorial, or highly arboreal, or where attraction to a group of conspecifics is a fundamental part of their social structure, are especially vulnerable.

Barriers to movement can result in a variety of deleterious effects on animal populations. Barriers to dispersal can bring about delayed maturation or skewed sex ratios (Wolff 1999) resulting in social dysfunction. Threats associated with gaps may elicit differing reactions based on sex (Gibeau and Herrero 1998, Nichols and Coffman 1999). Lack of genetic input can lead to inbreeding depression, and in the case of small isolated populations, result in local extinctions. Denial of access to denning sites, seasonal food resources, or calving areas may, in extreme situations, result in losses affecting entire populations (Spinage et al. 1989, Spinage 1992).

Results from previous studies point to a wide variety of responses in differing groups. Gap-crossing abilities would appear to be species specific and not entirely related to mobility. Some *Microtus* species are hesitant to cross 4 m gaps of mowed grass whereas mice (*Peromyscus*) under similar conditions have been found to cross over a 1-km gap (Wolff et al. 1997). The arboreal garden dormouse (*Eliomys quercinus*) can effectively cross open fields when forced to do so by translocation but will not attempt it under normal conditions (Bright 1998). Snowshoe hares (*Lepus americanus*), were inhibited from crossing a transmission line gap of 30 m (Doucet and Brown 1997). In an Alberta-based investigation, female grizzly bears (*Ursus*

arctos) were found to not cross highways in the Bow Valley corridor, severely curtailing their natural movement patterns (Gibeau and Herrero 1998).

Furbearers as a group, including the three focal species included in my work: northern flying squirrels, American red squirrels, and American marten, have borne little investigation into their gap-crossing abilities. Marten have been shown to be wary of open areas and prefer canopy cover (Soutiere 1979, Hargis and McCullogh 1984, Fredrickson and Bissonette 1990). While red squirrels are known to occur in forest patches in fragmented landscapes,it is not clear whether individuals disperse between and are successful in these patches in the mosaic, or whether individuals represent relict populations are not fully understood (Neil Darlow, Dept. Of Biology, U. Of Alberta, Edmonton, AB.). The gap-crossing abilities of northern flying squirrels are unknown. Southern flying squirrels, the only other member of the northern flying squirrel's genus *Glaucomys*, was unable to recolonize woodland patches in the absence of treed corridor connections to occupied patches (Rosenblatt et al 1998) and flying squirrels in Fenno-Scandia are adversely impacted by loss of connectivity in forested habitats (Monkkonen et al. 1997).

Industrial activity is expected to increase throughout northern Alberta over the coming decades. Relevant scientific research is a fundamental tool to allow resource managers to make informed decisions. The gap in the literature that currently exists with regard to linear disturbances in general, and pipelines ROWs in particular, was the incentive for the initiation of this study. In this chapter, my specific objective was to test whether pipeline ROWs constitute a movement barrier for northern flying squirrels, American red squirrels or American marten in the boreal mixedwood forest

in northwestern Alberta. I predicted that my narrowest width (15-27 m) class of ROW would not pose a barrier to movement for any species, the medium width (32-42 m)class would be a barrier to flying squirrels, and the largest width (72-92 m)

3.2 Methods

3.2.1 Study Area

My study site was situated 40-km south of Grande Prairie, Alberta with sampling grids located to the east and west of Highway 40. The study site encompassed 6 townships: Townships 67 Ranges 3 to 5 West 6th Meridian and Townships 68 Ranges 4 to 6 West 6th Meridian. Located in the mixedwood boreal forest, the dominant tree species was trembling aspen (*Populus tremuloides*) with significant numbers of balsam poplar (*Populus balsamifera*), white spruce (*Picea glauca*), and black spruce (*Picea marianna*) also present. The topography varied with the Smoky River, a major tributary, bisecting the area and several small creeks adjacent to the study plots. In the study area, industrial activity was relatively high and continued to increase throughout the duration of my study. Canadian Forest Products and Weyerhaeuser Company Ltd. carried out timber extraction in the form of clearcuts 30-50 ha in size. Oil and gas activity was also prevalent within my study area in the form of numerous well sites, both old and newly-drilled, connected via small pipeline rights-of-way to the main transportation lines. In addition, a major pipeline with associated large width ROW bisected the area. The building of roads was extensive and ongoing and the forest was interspersed with cutlines in varying stages of regrowth. Two cattle grazing leases were established in the area.

3.2.2 Site Selection

In total, 9 sites were established along the rights-of-way of pipelines greater than 5-years-old. Sites were selected using Phase III Vegetation Inventory maps followed by extensive ground-truthing to verify that accuracy of the Phase III forest cover designations. The forest cover selected was greater than 70-80 years and all sites were deciduous dominated. Shrub layer varied somewhat between sites (see Table 3.1 for general site description). Canopy height was approximately 25 m within sites. Due to the lack of ideal sites, two sites (sites 5 and 6) were located on the Campbell Creek Grazing Reserve and subject to varying degrees of cattle grazing. Sites were laid out using a compass and 50-m tape. Where possible, the sites overlay the bird-sampling grids established by Warren Fleming in 1998-99 (Fleming 2001) with the exception of sites 1, 9, 10, 11, and 12 which were located elsewhere.
In the 2000 field season, 6 sites were established within 2 width classes of rights-of-way, medium (32-42 m) and large (72-92 m). Each width class was replicated 3 times. In 2001, 3 sites of a small-width class (15-27 m) were added. Each site consisted of a treatment and control grid. The treatment grids were centered over the pipeline rights-of-way. Four of the sites were widened in the winter previous to sampling. The rights-of-way of the large-width class (sites 5, 6, and 9) were widened approximately 30 m with timber cleared in the winter of 1998-99 and the pipe layed in winter 1999-2000. Site 10 of the small-width class site had been widened in the winter of 2001 by 9 m. One large-treatment grid (site 9) was lost to logging in the winter (2000-2001), between field seasons. It was re-established immediately

adjacent to the original site with a 100-m overlap. At each site, the control grid was located a minimum of 200 m from the treatment grid. When possible, the control grid was oriented in the same direction as the treatment, parallel to the right-of way, as was the case for sites 2-9. At site 1, the control grid was oriented parallel to an adjacent pipeline. Extensive and ongoing industrial modification of forest patches severely limited the choice and this resulted in 2 sites (1 medium, 1 small) being located in close proximity (< 1 km) to a sour gas pumping station Table 3.1: A general description of sites sampled comparing relative content of deciduous and coniferous trees in the forest cover and relative density of the shrub layer.

Table 3.1: A general description of sites sampled comparing relative content of deciduous and coniferous trees in the forest cover and relative density of the shrub layer.

		Treatment			Control		
Site	ROW Width	[1]Deciduous	[1]Conifer	[2]Shrub Layer	[1]Deciduous	[1]Conifer	[2]Shrub Layer
1	41.5 m	H	T	H	H	N	M
3	32 m	H	T-M	M	H	M	H
4	34 m	H	M	H	H	T	H
5	91.5 m	H	T	L	H	T	L
6	72 m	H	M	L	H	H	L
9	78 m	H	T	M	H	M	M
10	27 m	H	L	M	H	L	L
11	15 m	H	M	L	H	M	L
12	24 m	H	L	H	H	L	H

[1] Codes refer to the relative content of deciduous trees(trembling aspen, balsalm poplar, and/or birch) and coniferous trees (white spruce) between grids N=none, T=trace, M=moderate, H=high

[2] Codes refer to the relative density of the shrubby layer between grids: L=low density, M=moderate density, H=high density

3.2.3 Sampling Grids and Trap Setup

Each 300-m by 500-m trapping grid consisted of 24 traps spaced at 100-m intervals, encompassing an area of 15 ha (Fig. 3.2). Tomahawk single entry, live-capture traps were used Traps were mounted with nails and wire on the largest tree within 5 m of the designated trap site except in 11 cases where the lack of suitable trees necessitated utilizing the largest tree within 10 m. Traps were attached at 1.5-2 m above ground horizontally on the trunk. Bedding consisting of raw cotton was placed in the back of the trap to guard against hypothermia in the captured animals. Two pieces of plywood measuring 15x30 cm were attached with elastic bands to the top and bottom of the trap to provide a measure of security against predation and to give better footing. A plastic freezer bag was then placed around the back 2/3 of the trap to protect captured animals against inclement weather and to keep the bedding dry.

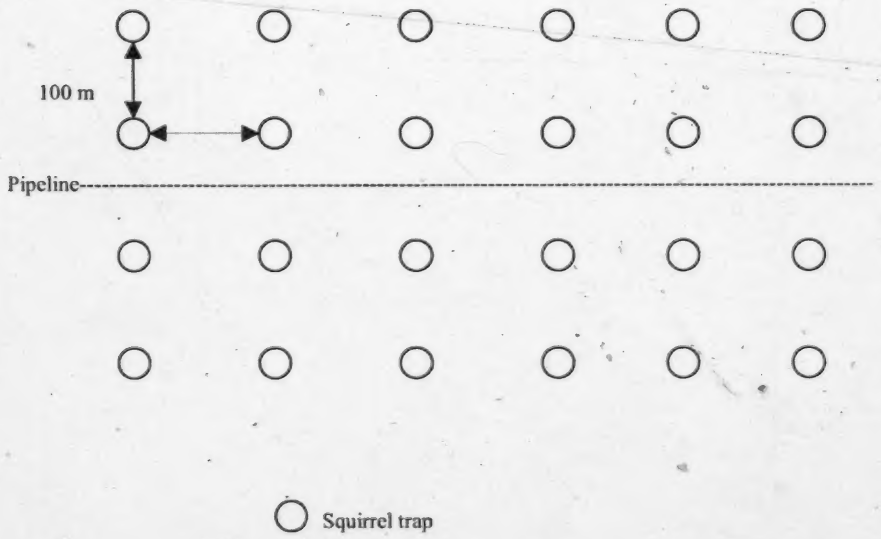

Figure 3.2: Grid overlay of pipeline right-of-way showing distribution of traps.

3.2.4 Bait

Traps were baited with water-soaked black oil sunflower seed and peanut butter (5-7 tablespoons). Slices of apple were added to provide a source of moisture. Pre-baiting a week in advance of trapping was conducted in 2000. Pre-baiting consisted of smearing the tree at trap height with peanut butter and sunflower seed and placing additional sunflower seed on the ground at the base of the tree. Pre-baiting was discontinued in 2001 because the combination of heavy rains and the taking of pre-bait by bears combined to render it ineffective.

3.2.5 Trapping Season, Duration and Daily Schedule

In both 2000 and 2001, 2 rounds of trapping were conducted. In 2000, trapping began June 7 and ended July 30. In 2001, trapping began on July 2, and the 2 rounds were completed on October 9. During round 1 of the 2000 field season, sites were trapped for 3 consecutive nights. This was extended to 5 consecutive nights in round 2 and throughout both rounds of the 2001 field season. Each round consisted of the simultaneous trapping of the treatments and controls in 2 sites, for a total of 96 traps set during a single night. Traps were set each evening between 1730hrs and 1830hrs and checked the following morning between 0600hrs and 1030hrs. Traps were closed during the day. Traps were not set on nights of heavy rain or wind because of low squirrel activity and safety concerns.

3.2.5 Animal Handling

Trapped squirrels were transferred to a "sock" made of soft canvas and mesh. Animals were then weighed using a hand-held Pesola scale, and examined so as to determine age (adult or juvenile), sex and general physical condition. Prior to release each animal was marked with a numbered aluminum ear tag, and released at point of capture. It was necessary to restrain some flying squirrels with a gloved hand to ascertain sex.

American marten had not initially been targeted as a study species but were included due to high trapping success in 2000. In the initial field season marten were not handled, as our handling socks would not hold them. Notation of highly individual pelage color, bib shape and color and ear notches allowed for identification of re-trapped individuals. A larger version of the squirrel holding sock was obtained for the 2001 field season and marten were then handled and tagged using the same method utilized for squirrels.

3.2.6 Data Analysis

I examined the movement across rights-of-way by marten and squirrels, by comparing movement across centerlines of all my grids to test for differences in crossing rates associated with the presence of a ROW. Each species was tested individually, by year, and width class. Crossing was assessed as a recapture on the opposite side of the ROW (in treatments) or center line (in controls) from a previous capture.

I first tested the data for normality using the Kolmogorov-Smirnov test (Dytham 1999). Because the data failed to meet the assumption of normality, non-parametric Mann-Whitney U tests were used. The Mann-Whitney U test was also used to compare ROW treatments for pooled data from all species, all years and all widths.

Crossings of the right-of-way were compared to crossings of a centerline of the control grids determined by bisecting the grid lengthways. Animals were deemed to have crossed when they were recaptured on the opposite side of the centreline from a previous capture. I analyzed my data by comparing results from treatment-control pairings for all 3 species, in all width classes for both years, and in combinations of years for each species and size class, and pooled for all three species for each year using the Mann-Whitney U test (Zar 1974, Dytham 1999,). P-value for all tests was set at 0.10 to lessen the possibility of a Type 2 error (Zar 1974, Dytham 1999). The statistics program used was SPSS 11.0 (Norusis 2003).

3.3 Results

Total number of captures for red squirrels, flying squirrels, and marten, in each width class, for both years, and numbers of crossings is shown in Table 3.2. In general, the number of captures was higher for all species in 2000, except in the large-width class in 2001, where a higher number of flying squirrels were captured. In total, 4 crossings of rights-of-way were detected: 1 red squirrel and 3 individual marten made 1 crossing each. No flying squirrels were observed to cross rights-of-way of any size, in either year. In 2000, 1 red squirrel and 1 marten were observed to

cross the right-of-way of the medium-width class. In 2001, 2 marten (1 occasion each) crossed the ROW in the small-width class. There were no crossings by any species of the large width class in either year. Combining all species and both years resulted in a total of 4 ROW crossings, whereas total crossings of the centerline of the control grids was 37, indicating a trend towards more random movement in the absence of the ROWs (Table 3.3)

While there were substantial differences in crossing captures of centerlines between treatment and control grids, overall, the number of crossings was low, and some grids had no crossing captures. Thus, my ability to evaluate these patterns statistically was limited, and few significant results emerged from analyses. At the species level, both the flying squirrel and red squirrels exhibited significantly fewer crossing captures on treatment grids positioned on large ROWs, than on paired control grids (Table 3.4). When all species were pooled, crossings over all width classes in treatment grids were significantly lower than those recorded in control grids (Table 3.4).

Table 3.2: Total number of individuals captured in control and treatment grids for small-, medium-, and large-width pipeline ROWs. The value in parentheses is the total number of captures. The number prefaced by a C is the number of crossings (see text for explanation).

		Small Width		Medium Width		Large Width	
Year	Species	Control	Treatment	Control	Treatment	Control	Treatment
2000	Flying Squirrel	n.a.	n.a.	7(8)	6(9)	7(10) **C1**	5(7)
2000	Red Squirrel	n.a.	n.a.	10(18)	32(56) **C1**	47(98) **C4**	26(46)
2000	Marten	n.a.	n.a.	9(21) **C1**	12 (16) **C1**	10(15)	12(18)
2001	Flying Squirrel	5(9)	6(8)	4(15)	3(4)	13(29) **C5**	19(31)
2001	Red Squirrel	2(5)	2(4)	5(5)	15(20)	38(70) **C2**	18(27)
2001	Marten	8(12)	6(8) **C2**	4(4)	3(4)	4(14) **C4**	4(7)

C indicates numbers of crossings of centerline

Table 3.3 Comparisons of numbers of movements not crossing centerlines and movements across centerlines of controls and treatments for all three species.

Species	Treatment		Control	
	Crossed	Didn't Cross	Crossed	Didn't Cross
Northern Flying Squirrel	0	18	4	15
Red Squirrel	1	44	16	64
Marten	3	13	17	10

Table 3.4 Analysis of crossing captures over center-lines of control-treatment pairs on and away from pipeline ROWS of varying width, for all species, width classes, and both years. No tests were performed in instances where neither treatment or control grids had crossing captures.

Year	Species	Width	Mann-Whitney U	Z	P-value (2-tailed)
2000	Northern Flying Squirrel	Large	3.000	-1.00	0.317
2001	Northern Flying Squirrel	Large	7.500	-1.55	0.121
2000-2001	Northern Flying Squirrel	Large	153.000	-1.78	**0.075**
2000	Northern Flying Squirrel	Both Widths	153.000	-1.00	0.317
2001	Northern Flying Squirrel	All Widths	337.500	-1.43	0.153
2000	American Red Squirrel	Large	0.000	-2.12	**0.034**
2000	American Red Squirrel	Medium	3.000	-1.00	0.317
2001	American Red Squirrel	Large	7.500	-1.58	0.114
2000-2001	American Red Squirrel	Large	117.000	-2.37	**0.018**
2000-2001	American Red Squirrel	Medium	153.000	-1.00	0.317
2000	American Red Squirrel	Both Widths	143.500	-1.07	0.283
2001	American Red Squirrel	All Widths	337.500	-1.43	0.153
2001	American Marten	Large	.000	-1.00	0.317
2001	American Marten	Small	3.000	-1.00	0.700
2000-2001	American Marten	Large	153.000	-1.00	0.317
2001	American Marten	All Widths	364.000	-0.03	0.979
2000	All Species	Both Widths	853.000	-2.11	**0.035**
2001	All Species	All Widths	310.500	-1.71	**0.087**

3.4 Discussion

Examination of potential barriers to movement is fundamental to the study of animals, particularly in landscapes experiencing rapid change due to human activities. I studied northern flying squirrels, American red squirrels, and American marten and

one aspect of their movement response to linear disturbance; namely, crossing buried pipeline ROWs. I predicted that the narrowest size class of ROW examined would not pose a barrier to movement for any species, the medium width class would be a barrier to flying squirrels, and the largest width class would pose a barrier to flying squirrels, red squirrels, and marten.

I found that very few animals of any species crossed the ROWs that I monitored. Crossings by marten were limited to two in the narrow width class and one in the medium width class. A single red squirrel was detected crossing a medium width class ROW. No flying squirrels were detected crossing any ROW of any size in either year. In the control grids, a total of seventeen crossings of the centerline occurred, including five by marten, and six each by flying squirrels and red squirrels. Qualitatively this suggests that ROWs may pose some barrier or filter to movement, especially for flying squirrels.

Results for both red squirrels and flying squirrels were significant when pooled over both years for the largest width class, suggesting that the largest width class had some inhibiting effect on movement. However, smaller numbers trapped adjacent to the smallest width class during only a single season of sampling and low total capture numbers and recaptures for all three species in individual width classes did not provide for robust analyses of patterns (see also Study Limitations).

Species Response

While no other studies have assessed the willingness or ability of flying squirrels to cross rights-of-ways, my general findings for this species are consistent

with work undertaken on 2 other closely related species of flying squirrel. In the boreal forest of Finland, researchers compared random landscapes with landscapes occupied by Eurasian flying squirrels (*Pteromys volans*) and found that habitat connectivity was an important feature associated with the presence of flying squirrels (Hanski 1998, Reunanen et al. 2001). As well, the closely related southern flying squirrel (*Glaucomys volans*) has been found incapable of reinvading small pockets of forest isolated in fields, but individuals were capable of recolonizing patches attached to adjacent intact forest by hedgerows (Rosenblatt et al. 1998). The results of these studies suggest that disruptions in habitat connectivity, such as by wide pipeline ROWs, may have a negative effect on the movement of flying squirrels.

These findings are further reinforced by examining the behaviors of other comparably sized arboreal mammals. For example, dormice in Britain were found to be able to cross gaps if translocated, but seemed unable or unwilling to enter and cross them on their own initiative (Bright 1998). Also, small gliding marsupials from Australia, equivalent in size and locomotory ability to flying squirrels, seem likewise limited in their ability to cross human-induced gaps in forest (Lindenmayer 1992, Lindenmayer et al. 1993). These studies suggest that arboreal species are sensitive to "gaps" in the forest. As species adapted to large intact habitats, they may have fewer strategies to cope with habitat alterations (Wolff 1999).

Although red squirrels comprised the majority of captures in both field seasons, only one squirrel was detected crossing a ROW and significant results were obtained for large width ROWs posing a barrier. This is in contrast to studies demonstrating the ability of red squirrels to persist, and show some of their greatest

densities, in forest fragments where movement between patches is inferred (Swihart and Nupp 1998).

Marten were detected crossing the ROWs on three occasions during my study. All crossings occurred on either small or medium-width ROWs, consistent with my prediction. In general, more movement was expected for marten, as the home ranges of marten are much larger than either of the squirrel species studied.

Factors Influencing Crossing

There are several factors associated with ROWs that may influence their crossing by small and medium sized mammals 1) predation, 2) home range size, and delineation, 3) seasonal variation in behaviour (i.e. juvenile dispersal, mating), 4) resource availability (i.e. food, den sites), 5) vegetation structure, and 6) human activity along ROWs. I cannot address any of these directly with my data, but provide the following review as context to the issues.

Predation

In my study area, there were several species capable of predating the focal species. Gaps and deforested corridors in forest are utilized by both avian and terrestrial predators for both hunting and travel. Great horned and great grey owls, in particular, use edges and gaps as primary hunting areas (Nero 1987). Owls are among the major predators of squirrels and the larger species are capable of capturing animals surpassing a small marten in weight. Great horned, great gray, barred, saw-

whet and boreal owls, all known squirrel predators (Teeple 1983, Voous 1988), were recorded in the area during the study.

Other potential predators, including hawks, weasels, foxes, lynx, and coyotes were seen or recorded in the study area and marten were present in high numbers (Luttich et al. 1970, MacDonald 1984, Wilson and Ruff 1999). Marten are regarded as a major predator of squirrels (Cowan and Mackay 1950, Raine 1981) and their presence in high numbers may have had an inhibiting effect on squirrels attempting crossings. In particular, squirrels are most vulnerable to predation when moving along the ground.

Travel along the ground was necessary if the flying squirrels were to cross the rows of the medium or large width classes examined. For example, flying squirrels commonly glide as far as 20 m and exceptionally to 90 m (Novak 1999, Wilson and Ruff 1999). Typically, flying squirrels glide at an angle of 30 to 40 degrees (Rezendes 1992). Assuming the height of aspen in my study area height was 30 m and the squirrel glides at an angle of 40 degrees, flying squirrels could glide no further than 25 m. A distance of 25 m does not exceed the widths of the medium- and large-width rights-of way sampled. Therefore, a flying squirrel attempting to cross these ROWs must travel along the ground for 7-66.5 m before reaching the opposite side, a considerable distance for a tree-dwelling species. On the ground, flying squirrels are extremely vulnerable to predation. Personal observations of flying squirrels released on the ground revealed them to be slower and less mobile than red squirrels. This lack of agility may render flying squirrels more susceptible than other similarly sized rodents to predation while on the ground and thus more hesitant to attempt crossings.

Nevertheless, the diurnal lifestyle of red squirrels makes them somewhat more susceptible to hawks than are flying squirrels, and in addition, several of the owl species noted in the area are diurnal or crepuscular hunters (Voous 1988).

Marten are also vulnerable to avian and terrestrial predators. Great horned owls, red foxes, and coyotes have been documented to predate marten (Baker 1992). Lynx and other large owl species also constitute other probable threats. Size dimorphism may make males somewhat less vulnerable to predation. Hawley and Newby (1957) suggested that marten avoidance of open spaces is in direct response to predation threats.

Home range

Home range size may also influence whether or not individuals of species are more prone to cross gaps. For example, flying squirrels with range sizes smaller than the area encompassed by an ROW would not incorporate the ROW into their home range, thus limiting crossings. Range size estimates for northern flying squirrels vary from 4.0 ha in Oregon (Witt 1992), to 2.45 ha for males, 1.95 ha for females, and 0.62 ha for juveniles in Maryland (Bendel and Gates 1987). Wiegl and Osgood (1974) found they inhabited a 100 to 200-m radius (~3-12.5 ha) in South Carolina, whereas Mowery and Zasada (1982) found that squirrels inhabiting Alaskan taiga required about 31 ha of optimal habitat. Flying squirrels in this study were recaptured in traps up to 300 m apart, suggesting they could have ranges that straddle the largest ROW width. Given that aspen dominated forest is not considered optimal habitat for this species, the flying squirrels examined in this study, in Alberta, may require home

ranges approaching the upper end of range sizes reported in the literature for intact coniferous forest.

As with flying squirrels, home ranges of red squirrels of insufficient size to straddle ROWs would limit crossing. Home range sizes varying from 2 to 8 ha have been recorded (Kemp and Keith 1970, Rusch and Reeder 1978) while Larsen and Boutin (1994) cite ranges 100 m in diameter (< 1 ha). Much of the work on red squirrels has examined range size in conifer-dominated habitats. No range sizes have been established for red squirrels in Alberta's aspen-dominated intact-forest sites. Home range sizes at the lower end of cited sizes would preclude red squirrels from crossing the largest ROW on a daily basis. However, red squirrels in this study, as evidenced by trapping, moved a minimum of 200 m within grids. This would make it feasible to cross any of the sampled ROWs.

Marten with range sizes recorded elsewhere would be faced with crossing man-made gaps on a regular basis in my study area. Home ranges cited in the literature vary from 0.8 to 19.9 km^2 for males, and 2.3 to 4.3 km^2 for females (Burnett 1981, Powell 1994, Mech and Rogers 1977), and some animals in the population may not have a home range (Buskirk and Powell 1994). Ranges recorded in logged forest are significantly larger than in forested areas, with clearcut areas having ranges up to 3.1 times the size of that of intact or selectively logged forest (Soutiere 1979, Thompson and Colgan 1987). Given the amount of habitat alteration associated with logging and other industrial activity in the study area, marten territories may have increased in size to compensate. Two marten in this study were recorded in both my treatment and control grids at a site, indicating a fairly large range size. For all

species examined, it is possible the ROWs act to delineate territories, thus reducing the probability that crossings, at least those representative of intra-territorial movements associated with foraging and other regular activities, would be recorded.

Seasonal variation in behavior (i.e. juvenile dispersal, mating)

Home range size may not represent the extent of movement of an individual over a year. Juvenile dispersal, exploratory forays, and the search for mates may account for movement outside of home ranges, but little data are available to quantify this.

Seasonal variation in flying squirrel behavior may influence gap crossing. Flying squirrels are thought to achieve full independence during late summer and fall (Soper 1964, Jackson 1961, Muul 1969). Presumably, this is be the time when exploratory movements to prospect territories are attempted. While newly independent juveniles were present in my sample, movement was not detected. One explanation is that they left the grids and were not recaptured. Mating in flying squirrels generally takes place in late winter or early spring, and entails forays of up to 500 m (Soper 1964, Wells-Gosling 1985), though there is some evidence to suggest breeding at other times (Dice and Sherman 1922).

Red squirrels may have a higher probability than flying squirrels of crossing ROWs during dispersal, exploratory forays, or during the mating season. Dispersal is not confined to young of the year. Up to one third of females bequeath their territory to their offspring each year (Price and Boutin 1993, Berteaux and Boutin 2000). Dispersal of red squirrels takes place in late summer and fall, and Rusch and Reeder (1978) found that territorial defense intensified in late summer. Dispersal distances up

to 1 km have been noted (Price and Boutin 1993, Larsen and Boutin 1994). Given grid sizes and trapping regime used in my, red squirrels could have dispersed out of the area without being detected. Breeding takes place in spring, prior to the commencement of trapping in this study.

Marten experience delayed implantation and mating takes place between June and August (Markley and Bassett 1942). Thus, males should have been actively seeking mating opportunities during my field seasons. Juvenile dispersal times in the literature range from mid-July through October (Archibald and Jessup 1984, Slough 1989). Distances of 40 to 50 km have been noted (Hawley and Newby 1957). Additional movements have been reported for mid-winter to early spring (Clark and Campbell 1976, Archibald and Jessup 1984,). Migratory movements of marten are anecdotal in nature and poorly documented (Buskirk 1983).

Resource availability (i.e. food, den sites)

Resource limitations could precipitate large-scale movements beyond fixed territories. Late summer should be a period of relative abundance in resources for flying squirrels. However, year-to-year variation in dietary staples such as fungi or cone crops could provoke forays beyond the normal home range boundaries. Shortages would probably be at their most acute in winter, making the risks of gap crossing relative to the potential benefits a more viable proposition at this time. Red squirrels are largely conifer cone dependent. Failure of the cone crop or other food resources in a given year could cause movement beyond the normal home range boundaries. Rusch and Reeder (1978), studying red squirrels in Alberta, found that

aspen-dominated sites were the least preferred habitat. Lower densities in sub-optimal habitats. Less dense populations may lessen competition and associated movement. Conversely a less than optimal habitat may necessitate larger territories or more movement in search of more widely spread resources.

Marten are dependent to some degree upon prey populations (microtines, snowshoe hares) which are cyclical (Thompson and Colgan 1987). Marten populations shown to drop precipitously after logging (Thompson and Harestad 1994, Potvin et al. 2000) and these population decreases may be the result of marten moving in response to habitat degradation and alteration to the prey base or loss of suitable den sites.

Vegetative structure

Vegetation structure in the ROWs, and in the forest edges immediately adjacent may influence crossing. ROWs in my study had varying amounts of regrowth vegetation associated with them. Mowing of grass in 4-m strips has proved an impassable barrier to voles (Lidicker and Peterson 1999). Snowshoe hares in a Quebec study foraged along the edges of, but did not cross, a 30-m transmission line gap until vegetation grew sufficiently to afford cover in the second winter of the study (Doucet and Brown 1997). Variations in regrowth in my sites had no appreciable effect on flying squirrel crossing. No ROWs had shrubs or trees growing in them, of sufficient height to serve as suitable launch sites for gliding. Answering this question properly requires examining ROWs that vary not only in width but also in vegetation density and height. Possibly ROWs that are allowed to retain even scattered trees tall

enough to allow purely arboreal crossings may make the ROW permeable to flying squirrels.

For marten, a general pattern of avoidance of areas devoid of overhead cover has been noted (Hawley and Newby 1957, Buskirk and Powell 1994). A Colorado study found marten to avoid areas greater than 23 m from the forest edge (Robinson 1953). However, documented gap crossings have ranged from 10 to 100 m (Kohler and Hornocker 1977, Spencer et al. 1983), and home range shifts entailing the crossing of 300-m openings have been recorded (Buskirk 1983). Accounts of behavior while crossing also vary, with some authors describing foraging while crossing clearcuts (Soutiere 1979), while most note marten crossing openings directly, by the shortest route available (e.g., Hargis and McCullough 1984).

Marten studies have identified a preference for habitat with good canopy cover or thick herbaceous vegetation with tree boles and surface debris. This is assumed to be in response to predation threats. However, there seems to be some regional variation in habitat requirements, with marten at the northernmost extent of their range, in Alaska and Yukon, using forests with sparse canopy (Buskirk 1983, Magoun and Vernam 1986). Additionally, marten have been found several kilometres from trees above the treeline on talus slopes (Grinnel et al. 1937, Streeter and Braun 1968). Perhaps talus provides alternative shelter, or possibly perceived predation risks are somewhat lower in these areas.

Overall, the literature generally identifies a preference for conifer-dominated habitats (Allen 1982, Buskirk and Powell 1994). This contrasts with Potvin et al. (2000) who found a distinct preference for deciduous or mixedwood stands during

winter in their Quebec radio-tracking study. Comments during the present study by two Grande Prairie trappers were of interest in this regard. Both stated that formerly marten in the area were not found in deciduous-dominated forest, but had moved in over the last two decades and were now trapped there regularly (Ken Lawrence, Ed Lightfoot, Campbell Creek Grazing Reserve, Grande Prairie, AB).

Human activity

Human activity along the ROWs is an additional factor to consider when assessing response, however, the sites I studied received little use by humans during the summer and fall trapping periods. As opposed to roads or some other human habitat alterations, once ROWs are in place they often have a low human presence. Monitoring or vegetation control is very infrequent, often annually or less. ROWs do allow access into forest interior by trappers, hunters and recreational users, but these are almost invariably during daylight hours. As such, this would seem to pose little disturbance threat to flying squirrels. Therefore, it is unlikely that human activity along rows inhibits the movement of flying squirrels.

For reasons given for flying squirrels, human activity along ROWs probably constitutes a low level of disturbance for red squirrels, after initial habitat alteration and ROW construction. However, red squirrels are still actively harvested for fur and ROWs may provide additional access to the forest by hunters. Human activity along ROWs may also be of minimal importance to marten under most post-construction conditions, excepting the increased ease of access for trappers.

Study Limitations

My study design was not optimal for undertaking a thorough appraisal of gap crossing propensities in my focal species. Radio collaring would allow more detailed identification of individual movement without the invasiveness of routine recapturing. However, the resolution of locations might be insufficient to yield detailed information on movement, although it should be sufficient to determine whether animals are located on one or the other side of a ROW. Extending the field season throughout the winter and early spring might shed light on movements associated with breeding or resource failure.

Experimental relocation to the opposite side of the ROW, to look at rate of return to home range, is an additional method to evaluate crossing ability. While it has the benefit of standardizing motivation, it may induce movements in animals which are not natural (Bright 1998).

Rusch and Reeder (1978) looked at activity periods for red squirrels in Alberta and found their highest activity levels to correspond with the morning and late afternoon time periods when my traps were still open. However, a trapping regime that covered the entire diurnal period may have been more likely to detect crossings by this species. Marten are also primarily diurnal, with some nocturnal activity (Hauptman 1979). A trapping regime operating throughout daylight hours may have more accurately assessed their gap crossing capabilities, as well.

To fully understand the movement of marten in the study area, trapping or snow-tracking through the winter period could provide more comprehensive data. Radio-collaring to look at dispersal and to delineate home ranges in undisturbed

boreal mixedwood forest, for comparison with areas currently under development, is needed to provide baseline data for management.

Populations of red squirrels and marten are believed to fluctuate in accordance with food resource availability (Thompson and Colgan 1987, Novak 1999). Trapping can also have an effect on local populations. For undetermined reasons, there were notably fewer red squirrels and marten in the 2001 field season. Researchers from the Alberta Research Council also noted low numbers of squirrels in the Grande Prairie during 2001 (Samantha Song, biologist, CWS, Edmonton, AB). However, given the paired control-treatment design of this study, variation in annual abundances should not have influenced my results.

3.6 Conclusions

Despite identified limitations in study design and low capture rates, I found some evidence the pipeline ROWs I sampled posed movement barriers to the focal species included in this study. Given the increasing preponderance of these features in northern Albertan landscapes, these indications suggest that further research is warranted into movement response to, and ultimately the population consequences of, such landscape change.

Chapter 4. General Conclusions and Recommendations

4.0 Conclusions

Among the many anthropomorphically induced changes currently modifying the mixedwood boreal forest of northern Alberta, buried pipeline ROWs are among the most visible and widespread. ROWs differ from other linear disturbances in a number of ways and studies examining the response of wildlife to transmission lines or roads may not represent the effects associated with pipeline ROWs. Features that set ROWs apart from other linear disturbances are 1) limited human presence, 2) absence of structures in the ROW (e.g. as compared to power lines), and 3) lack of vehicular traffic. Little research has been specifically directed towards examining the effects of ROWs on wildlife. Current knowledge, which is limited to relatively few species, does not allow comprehensive evaluation of the overall effect of ROWs on the boreal forest ecosystem.

As demonstrated by this study, flying squirrels, red squirrels and marten are widespread in this region and readily trapped. They also occur in sufficient numbers to allow their use as subjects when seeking insights into the possible effects of ROWs on wildlife. While I found little indication that animal numbers were affected by the presence of ROWs, at least during summer and early fall, the results of my study suggest that ROWs may act as barriers or filters to movement, which indicates that further research focusing on these and additional species occurring in the region is warranted.

4.1 Recommendations for Further Research

There are several ways by which research might proceed:

1. Although I had relatively low sample numbers, I believe that mark-recapture methods with some modifications would be an effective tool for examining the effects of ROWs on the movement of squirrels and marten. I recommend that future mark-recapture surveys extend the sampling over a longer period (i.e. more than 2 trapping sessions) or concentrate on subsets of the population most likely to undertake extra-territorial forays (e.g., juveniles). Expanding the overall size of the grids would increase captures and provide more powerful tests for density effects, and extending the length of the trapping grids along the ROW might allow for greater possibility of detecting crossings. While not able to detect long distance emigration, this method could be used to examine initial experimental movements by individuals and might reveal changes in distances moved to establish new territories in fragmented habitats. Experimental relocation (i.e. translocation) is often employed with trapping studies to access the ability of individuals to cross certain features, such as pipeline ROWs . In general the limitations of mark-recapture methods are that they are highly invasive, labour intensive, and require additional animal care safeguards if trapping is carried on in winter. Also, the data gathered are limited to a narrow range of target species. 2. Radio-collaring of individuals, while also intrusive, would allow for intensive data collection over a relatively short period of time. Although radio-collaring has been successfully used with the focal species in previous studies (Weigl and Osgood 1974, Mowery and Zasada 1982), some problems can arise with flying

squirrels as a result of ligaments on the patagium being caught on the collar. Careful monitoring subsequent to collaring is essential to avoid associated mortalities (Patrick Perdichuk, flying squirrel researcher (retired), Edmonton, AB.). Radio-collaring could also be used in conjunction with translocation experiments.

Intensive data collection utilizing radio-telemetry could assess the number of crossings and exact parameters of movement of individuals, in addition to information on activities in habitat adjacent to the ROW. Home range sizes both near and away from ROWs and during different seasons, reproductive success, dispersal patterns, and mortality causes would also be within the scope of this method. Drawbacks include initial expense and labour intensity.

3. I recommend the use of snow-tracking to study movement across ROWs. Snow-tracking is a viable and effective means of accessing movement across ROWs in winter. This method can be used to gather data from a broad array of species active in the boreal forest in winter (e.g. red squirrels, mustelids, lagomorphs, ungulates, canids, felids, and grouse). Data gathered might allow for evaluation of avoidance, community composition and population density questions. Multi-year monitoring would be most effective so as to account for temporal variation in snowfall, and population cycles, which could influence results. Initial results could lead to selection of representative species demonstrating behavioural responses to the ROWs, which could then be chosen for more detailed study. The advantages of this method are that it is non-invasive, does not affect the natural

movements of animals, and can be accomplished with relatively low cost and labour intensity.

4. Research examining the perceptual range (the range at which an animal can perceive a landscape element as such) of various species has recently shed light on a relatively unexamined component of animal movement and dispersal capabilities (Zollner and Lima 1997). Indications are that rodents orientate by vision when seeking out distant patches of habitat. Studies of visual acuity, as it relates to detection-at-a-distance abilities, seem to be scaled in relation to body size (Mech and Zollner 2002). Given that movement ability is also dependent on size (Wolff 1999,), the result may be that taxa at the smaller end of the scale are inherently less able to respond to habitat fragmentation due to an inability to perceive patches as potential habitat. Initial studies indicate that species adapted to contiguous forested habitats may be particularly vulnerable and may be incapable of perceiving tertial habitat beyond relatively short distances (Zollner and Lima 1997). If this is the case for species in the boreal, ROWs of sufficient width may inhibit the ability of the species to detect habitat on the other side. Future study might allow for establishment of maximum widths to allow unhindered crossing by specific species.

4.2 Management Recommendations

At present, there is insufficient information available to evaluatewhether constructing several small, versus a single large, pipeline ROW would minimize adverse effects of such developments on the species I studied, over large areas. To

mitigate the potentially negative effects of very wide (ca. >70 m) ROWs on the movement of wildlife, I recommend the establishment and testing of corridors spanning ROWs , to assess their effectiveness in facilitating movement across ROWs. Response of focal species could be assessed with radio-collaring and/or track counts. Guidelines for vegetation management, in particular tree retention and/or restoration, could be derived from research on biotic response to such treatments in the context of forest harvesting. Corridors have been successfully used with a wide variety of taxa including amphibians (Reh and Seitz 1990), large carnivores (Gibeau and Herrero 1998), and ungulates (Dominske 1997). Designs have ranged from single species solutions to those aimed at facilitating use by a full complement of terrestrial species. Designs should be sought that benefit a large portion of the boreal community, although flying squirrels, due to their unique locomotory adaptations, may need corridors with specific attributes Research is being directed at various aspects of reserve and corridor design in search of specific requirements for varying taxa (Beier 1993, Harrison 1992, Schultz 1998, Tiebout and Anderson 1997)). Previous studies have indicated that corridors situated at crossings previously established by animal movement are utilized more frequently (Busby 1988). Use of traditional corridors may be a learned process in long-lived species and long-term monitoring is essential to gauge the efficacy of these mitigation efforts. Consulting biologists and pipeline company representatives should be involved in determining vegetative structure, and designing corridors, that enable pipeline maintenance while also facilitating wildlife use. Such approaches may be costly and labour intensive with respect to monitoring, but may answer some fundamental questions regarding possible mitigation efforts.

Results of research on pipeline ROWs and their associated effects must be evaluated in combination with the effects of other anthropomorphic and natural changes in the mixedwood boreal forest, in order to evaluate cumulative effects. Fragmentation thresholds for various taxa beyond which maintenance of species community structure and overall ecosystem integrity cannot be assured, is essential to allow for long-term planning.

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